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## DESCRIPTION

### FLUORESCENT LAMP AND MANUFACTURING METHOD THEREOF, AND LIGHTING APPARATUS

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#### Technical Field

The present invention relates to a fluorescent lamp and a manufacturing method thereof, and to a lighting apparatus using the fluorescent lamp.

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#### Background Art

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Fluorescent lamps of straight tube shapes, ring shapes, and single-ended shapes are known as general fluorescent lamps, and particularly, in view of recent demands for energy conservation and conservation of resources, a small-diameter ring-shaped fluorescent lamp for high-frequency lighting has been developed and produced as a product. This small-diameter ring-shaped fluorescent lamp is identified by the name "FHC" in products (see Patent Document 1). This small-diameter ring-shaped fluorescent lamp has approximately the same external diameter for the ring size as that of conventional ring-shaped fluorescent lamps, but the external diameter of the tube is made to be smaller, while ensuring brightness equal to or greater than that of the conventional ring-shaped fluorescent lamps, thereby satisfying the needs for energy conservation and conservation of resources and, particularly, allowing a comfortable visual environment to be realized in the home space.

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On the other hand, a square-shaped fluorescent lamp has been conventionally known (see Patent Documents 2 and 3). The fluorescent lamp described in the Patent Document 2 is a 30 W type square fluorescent lamp using a quadrate bulb having an external diameter for the tube of 25 to 32 mm, a curvature radius at the inner side of the bent portions of 20 to 40 mm, and an external diameter of 190 to 220 mm between opposing straight portions. The fluorescent lamp described in the Patent Document 3 is square fluorescent lamp using a quadrate bulb having an external diameter for the tube of 12.75 to 13.25 mm, an external diameter of 135 mm between opposing straight portions, and a discharge path length of 450 to 470 mm (tube length 500 to 520 mm).

[Patent Document 1] Japanese Patent No. 3055769

[Patent Document 2] Japanese Patent Laid-open Publication No. SHO 58-152365

[Patent Document 3] Japanese Patent Laid-open Publication No. HEI 3-59548

The small-diameter ring-shaped fluorescent lamp according to the Patent Document 1 is manufactured by forming a protective layer and phosphor layer in a straight tube bulb, the sealing electrodes to both ends, heating so that the entire straight tube bulb becomes soft, and bending the straight tube bulb into a ring shape, so that the initial light flux tends to be lower due to thermal deterioration of the phosphor layer. Further, alkali component in the bulb precipitates due to the heating process and reacts with the phosphor layer, thus providing problems of being easily deteriorated

in time elapsing and easily deteriorating the lumen maintenance factor.

Moreover, small-diameter ring-shaped fluorescent lamps are formed into the ring shape by a straight tube bulb while being stretched in the longitudinal direction, which easily results in the cracking of the protective layer and phosphor layer formed in the straight tube at the time of shaping, thus providing a problem that the protective layer and phosphor layer cannot be formed thickly. Generally, the thicker the phosphor layer is formed, the more the initial light flux improves, and a thicker protective layer allows the luminous flux maintenance factor to be improved. However, with small-diameter ring-shaped fluorescent lamps, the protective layer and phosphor layer cannot be formed thickly by the reasons mentioned above, so that there has been a limit to the extent of improvement in initial light flux and improvement in luminous flux maintenance factor.

The square fluorescent lamp according to the Patent Document 2 simply shapes a common large-diameter 30 W fluorescent lamp into a square, and no consideration has been given to the bulb shaping process or improvement in lamp properties.

Since the square fluorescent lamp according to the Patent Document 3 has a short tube length of 500 to 520 mm, the light output is low, and high-output lighting as like as in the conventional small-diameter ring-shaped fluorescent lamps cannot be expected. Particularly, the external diameter between opposing straight portions of 135 mm is so short that a pair of electrodes

must be disposed in a manner bent toward the inner side of the bulb, leading to inconveniences such that manufacturing is complicated, and that concentric combination arrangements of the same type of bulbs with the same shape but different dimensions cannot be used.

5 It is an object of the present invention to provide a fluorescent lamp which is small in size, highly efficient, and has improved light output properties, and a lighting apparatus using this fluorescent lamp.

#### 10 Disclosure of The Invention

The fluorescent lamp of the present invention comprises:

a bulb formed by: heating a bent-portion-formation preordination portion of a single straight-tube-shaped bulb member having an external tube diameter of 12 to 20 mm and a tube length  
15 of 800 to 2500 mm so as to provide a plurality of bent portions and straight tube portions adjacent to the bent portions by bending working, such that the straight portions are disposed generally within the same plane through the bent portions; forming in close proximity a pair of end portions with electrodes being sealed therein  
20 so as to form a single discharge path through the straight tube portions and bent portions; forming a phosphor layer on the inner surface of the bulb; and sealing a discharge medium including mercury; and

a base provided on the end portions of the bulb.

25 The bulb is formed of a plurality of straight tube portions and bent portions connecting these straight tube portions so as to be

communicated with each other. The bent portions are formed by heating bent-portion-formation preordination portions on a single straight-tube-shaped bulb and bending the portions. This may be formed by bending multiple straight-tube-shaped bulbs and  
5 connecting the end portions one another.

The bent portions may be a straight-tube-shaped bulb which is simply bent or may be shaped by wrapping on drum or by molding so that the cross-sectional shape of the bent portion is approximately the same shape as that of the straight tube portion.

10 The tube length of the straight-tube-shaped bulb is approximately the same as the discharge path length, and accordingly, it is necessary for the tube length to be within the range of 800 to 3000 mm, preferably within the range of 800 to 2500 mm, taking into consideration yielding light output equivalent to  
15 that of conventional small-diameter ring-shaped fluorescent lamps.

The inner diameter of the straight tube portion is within the range of 12 to 20 mm, and the optimal range of the inner diameter of the straight tube portion is 14 to 18 mm, taking into consideration lamp properties such as lamp efficiency and  
20 manufacturing conditions. It is to be noted that although the straight tube portion close to the bent portions may have an external diameter, which has changed, not within the above range due to the shaping of the bent portion, it is sufficient for the present invention that the greater part of the straight tube portion is within  
25 the range mentioned above.

It is known that generally, the smaller the tube diameter of a

fluorescent lamp is, the more the lamp efficiency improves, and in the present invention, the external tube diameter of the straight portions is 20 mm or smaller. An external tube diameter of 20 mm or smaller for the straight portions enables the lamp efficiency  
5 equivalent to that of conventional small-diameter ring-shaped fluorescent lamps to be realized. On the other hand, an arrangement of the external tube diameter of the straight portion being smaller than 12 mm is not acceptable because it is difficult to ensure the mechanical strength of the glass bulb having the bent  
10 portion, and also such arrangement is impractical because the lamp efficiency equivalent to that of conventional ring-shaped fluorescent lamps of the same size is not obtainable.

In order to improve the lamp efficiency of the conventional ring-shaped fluorescent lamp having an external tube diameter of 29  
15 mm (type name "FCL") by 10% or more, the external tube diameter needs to be reduced to 65% or smaller. That is, it will be necessary to provide an external tube diameter of 18 mm or smaller for the straight tube portion. Further, it is sufficient for the external tube diameter to reduce the thickness of the fluorescent lamp. Taking  
20 the properties such as light output and lamp efficiency into consideration, it is preferred that the external tube diameter at the straight tube portions is 14 mm or more.

A bulb has three or more straight tube portions, and the bent portions for connecting the straight tube portions are formed with  
25 the number less, by one, than number of the straight tube portions. The bent portions are formed such that the straight tube portions

are positioned substantially within the same plane. Electrodes are sealed in the end portions of the straight tube portions disposed at both ends at which no bent portion is provided, so that both end portions of the electrodes are closely positioned.

5       The bulb forms a single discharge path surrounding substantially the center in the positional relation of the multiple straight tube portions. That is, in the bulb, the interior of the straight tube portions is connected by the bent portions, and a single discharge path is formed by the pair of electrodes sealed in  
10 both end portions. Further, the straight tube portions need not to have the same length, and an arrangement, in which only one having a different length is disposed, may be adopted. In a case where four straight tube portions having the same tube length are connected with three bent portions, the bulb will provide  
15 approximately quadrate shape due to the straight tube portions.

It is sufficient that the shape of the bulb has a polygonal shape, which is not limited thereto, and the bulb may have a pentagonal or hexagonal shape. Furthermore, there may be further adopted that an arrangement in which two bulbs having different lengths of each  
20 side are concentrically disposed on the same plane, one on the inner side and the other on the outer side, and the end portions of the bulbs may be connected in an airtight manner so as to form a double tube.

The phosphor layer is to be coated and formed on the inner  
25 surface of the straight-tube-shaped bulb before shaping the bent portions.

The base has an electrical connecting portion connected to a supply member such as a socket. This connecting portion may be provided at a position apart from both end portions of the bulb. Further, the base may have a configuration serving as a holding  
5 portion through a mechanical connection to the supply member.

According to the present invention, only the bent-portion-formation preordination portions of a straight-tube-shaped bulb having an external tube diameter of 12 to 20 mm are heated so as to be softened, and bent portions are formed so that the thermal  
10 deterioration of the phosphor layer formed at the straight tube portions is alleviated and the depreciation of the initial light flux is suppressed, thereby lighting the lamp with higher efficiency.

Furthermore, the straight tube portions of the bulb are not bent under the thermal softening, so that cracking or peeling of the  
15 phosphor layer and protective layer do not readily occur even in the event that the phosphor layer and protective layer are formed thickly, and poor appearance and deterioration in lumen maintenance factor due to such cracking or peeling can be improved.

According to the fluorescent lamp of the structures and  
20 characters mentioned above, the bent-portion-formation preordination portions are preferably bent such that the radius of curvature at the inner side surface of the bent portion is in a range of 1 to 3 times the outer diameter of the tube, and the amount  
( $\text{mg}/\text{cm}^2$ ) of phosphor layer adhering to the bent portions is  $1/2$  or  
25 more than that at the straight tube portions.

According to an arrangement in which the radius of curvature



at the inner side surface of the bent portion is small, the stretching of glass at the outer side of the bent portion is great, and the phosphor layer readily peels. However, with the arrangement of the present invention, a straight tube bulb having an external tube diameter of 12 to 20 mm is bent, so that the stretching of glass at the outer side can be made smaller than that of the conventional straight tube bulb having an external tube diameter of 25 mm or greater. However, in the event that the radius of curvature at the inner side surface is smaller than the external tube diameter, since the peeling of the phosphor layer remarkably occurs, it is necessary for the radius of curvature to be equal to or greater than the external tube diameter. Furthermore, with the bent portion in which the radius of curvature at the inner side surface is more than three times the external tube diameter of the straight tube portion, the percentage of bent portions in the bulb obtained by bending the straight tube bulb with a tube length of 800 to 2500 mm becomes great, thus not expecting the improvement in lamp efficiency. In addition, the shape of the bulb has gradually curving bent portion, so the discharge path length becomes small, and also the appearance of a polygonal bulb is diminished. Thus, the radius of curvature needs to be three times, or smaller than, the external tube diameter of the straight tube portions.

Furthermore, the amount of the phosphor layer adhering to the bent portion is less per area increment ( $\text{mg}/\text{cm}^2$ ) because the outer side glass portion stretches, but the peeling of the phosphor layer can be made inconspicuous by adjusting the stretching of the glass

portion at the outside when bending the bent-portion-formation preordination portion so that the amount adhering becomes 1/2 of or more than that at the straight tube portion, and the desired light output is also obtainable from the bent portion.

5       The bent portion is defined herein as a region between points at which the curving inner surface and outer surface meet to the outer peripheral surface of the adjacent straight tube portions. Accordingly, while this matter may not necessarily accord with the bent-portion-formation preordination portions of the straight-tube-  
10   shaped bulb, it is of course desirable that the bending working is carried out with small difference therebetween.

      According to the above fluorescent lamp, the application amount of fluorescent substance particles at the straight tube portions is preferably 4.0 to 7.5 mg/cm<sup>2</sup>. In the event that the  
15   application amount is less than 4.0 mg, the advantage in the improvement in the light output over the conventional small-diameter ring-shaped fluorescent lamps will be reduced. On the other hand, in the event that the application amount of fluorescent substance particles at the straight tube portions exceeds 6.0  
20   mg/cm<sup>2</sup>, the phosphor layer may begin to be peeled at the bent portions, and when exceeding 7.5 mg/cm<sup>2</sup>, an advantage in the improvement in the light output due to the increasing of the thickness of the phosphor layer will not remarkably appear.

      Accordingly, with an application amount of phosphor particles  
25   making up the phosphor layer at the straight tube portions of 4.0 to 7.5 mg/cm<sup>2</sup>, the light output can be improved, and by setting this

range to 4.0 to 6.0 mg/cm<sup>2</sup> the cracking and peeling of the phosphor layer can be suppressed at the straight tube portions.

Furthermore, according to the above fluorescent lamp, the bent-portion-formation preordination portions has a length in a  
5 range of 5 to 50% of the entire length of the straight-tube-shaped bulb, preferably within a range of 15 to 50%.

The greater the percentage of the straight tube portions, which have small thermal deterioration of the phosphor layer, is as to the entire bulb, the smaller the deterioration in the initial light flux is,  
10 and the greater the improvement in the light output is. Accordingly, the length of the bent-portion-formation preordination portions is 50% of the entire length of the straight-tube-shaped bulb or less. In the event that the length of the bent-portion-formation preordination portions exceeds 50%, the amount of phosphor layer which  
15 deteriorates due to the heat at the time of bending will be increased, and improvement in the light output is made worse. On the other hand, in the event that the length of the bent-portion-formation preordination portions is less than 5%, it becomes difficult to bend the portions to be bent, and it is also difficult to obtain a required  
20 mechanical strength of the bent portions.

With the arrangement mentioned above, since the length of the bent-portion-formation preordination portions is within a range of 5 to 50% of the entire length of the straight-tube-shaped bulb, the length of the straight tube portions, which have small thermal  
25 deterioration of the phosphor layer, becomes suitably great. Accordingly, it is easy to be manufactured, the mechanical strength

can be ensured, and a fluorescent lamp with the high improvement in the light output can be realized.

According to the fluorescent lamp of the characters mentioned above, a protective layer of 0.5  $\mu\text{m}$  or more in thickness may be

5 formed on the inner surface of the bulb.

In the event that the protective layer has a thickness of 0.5  $\mu\text{m}$  or more, cracking of the phosphor layer or protective layer at the bent portions could be suppressed, and also reaction between the alkali component in the bulb and mercury, and the phenomenon of  
10 mercury injection into the bulb can be expected to be suppressed, thereby reducing consumption of the mercury during the lighting of the lamp. Moreover, since the straight tube portion is not essentially stretched, there is no fear of cracking or the like of the protective layer at the straight tube portion during the bending  
15 process even in the event that the thickness of the protective layer formed in the straight-tube-shaped bulb is increased to 0.5  $\mu\text{m}$  or more, so that the functions of the protective layer can be fully manifested.

In addition, according to the present invention, in the case of  
20 the fluorescent lamp protective layer having the thickness of 0.5  $\mu\text{m}$  or more, in addition to the function of the protective layer, the amount of mercury consumption is greatly reduced in conjunction with the straight tube portions not being directly heated to the point of softening. Accordingly, even with 0.15 mg/W or less mercury  
25 sealed in per lamp wattage, it has been confirmed that the mercury is not depleted during the rated life expectancy of the lamp, and the

lamp can remain lighting throughout.

In the above fluorescent lamp, the bulb is formed in an approximately quadrate shape from five straight tube portions, with bent portions formed at each of the diagonal line positions of the quadrate shape, with a base provided on both end portions of the bulb at substantially the center of one side of the quadrate shape.

According to this configuration, a light source, in which the light emission portion forms the sides of the quadrate shape, can be provided, and the base is disposed substantially at the center of one side of the quadrate shape, so that both the end portions of the bulb are disposed on substantially the same line, thereby enabling the structure for attaching the base to be simplified.

Preferably, the fluorescent lamp of the structure mentioned above further comprises a turn restricting member for restricting the turning angle of the base with respect to both the end portions of the bulb to within a predetermined angle.

According to this configuration, turning of the base over a predetermined angle can be restricted by the turn restricting member so as to prevent outer leads, which are connected to the pair of electrodes, then extend through both the end portions of the bulb in an airtight manner outside and are connected to the terminals of the base such as pins, from being pulled and broken, or to prevent the end portions of the bulb from being broken or prevent the damage of the lighting circuit due to the pair of outer leads short-circuiting one another, or from being pulled off of the portion fused to the base pins or the like.

The turning restriction angle is preferably within  $45^\circ$  for both forward and reverse turning directions. This is based on the reason that the connectable range with the electric supply socket on the lighting apparatus side can be enlarged by suitably adjusting the position of the base pins while turning the base in the forward and reverse directions within  $45^\circ$  each, while preventing damage of the lighting circuit and breakage of the end portions of the glass bulb due to breaking of the outer leads and short-circuiting of the pair of outer leads one another.

Furthermore, according to the above fluorescent lamp, the turn restricting members are configured by both the base and both end portions of the bulb to which the base is fitted so as to provide an elliptical shape in its axial cross-sectional shape.

According to this configuration, both the base and the end portions of the bulb to which the base is fitted have the elliptical axial cross-sectional shapes, thus preventing the turning of the base. Accordingly, the braking or coming loose of both the outer leads, damage of the lighting circuit and breakage of the end portions of the bulb due to the short-circuiting of the pair of outer leads, and breaking of the bulb ends, can be prevented.

In the above fluorescent lamp, the turn restricting members are formed on at least one of both the joint portions of the base and the end portions of the bulb to which the base is fitted and may be constituted as retaining members for restricting the turning of the base exceeding a predetermined angle by retaining the base.

According to this configuration, the turning restriction angle

can be set by the retaining members in an accurate manner.

The present invention further provides a fluorescent lamp comprising:

a bulb formed by: connecting a plurality of straight tube  
5 portions having an external tube diameter of 12 to 20 mm within a  
same plane through bent portions; forming in close proximity a pair  
of end portions with electrodes being sealed therein so as to form a  
single discharge path through the straight tube portions and bent  
portions; forming a phosphor layer on an inner surface of the bulb;  
10 and sealing a discharge medium including mercury; and

a base provided on the end portions of the bulb,  
wherein a coldest portion to be maximally cooled is formed to  
at least one of the bent portions at a time of lighting.

With the fluorescent lamp according to this invention, the  
15 coldest portions are formed at the bent portions of the bulb having  
straight tube portions with an external tube diameter of 12 to 20  
mm, so that the coldest portions can be ensured without reducing  
the discharge path by extending the distance from the electrodes to  
the bulb ends more than necessary, thereby further improving the  
20 lamp efficiency.

According to the above fluorescent lamp, the maximum length  
of the inner tube diameter at the bent portions is preferably 1.2  
times the inner tube diameter of the straight tube portions, or more.

The inner tube diameter at the bent portion mentioned herein  
25 means the inner diameter in the direction orthogonal to the axial  
center of the discharge path, and in a case that the cross-sectional

shape of the bent portion in this direction is not a true circle, this means the greatest width dimension within the cross-section.

In order to form the coldest portion, it is necessary to enlarge a so-called non-discharge region in which no discharge is formed.

5 However, in the bulb having an outer tube diameter of the straight tube portion of 12 to 20 mm, it was confirmed through an experiment that the desired coldest portion temperature could be substantially ensured with an inner tube diameter, at the bent portions, 1.2 times or more the inner tube diameter at the straight  
10 tube portions, though this depends on the magnitude of the input electric power. Further, in order to further ensure the coldest portion, the inner tube diameter at the bent portion is preferably 1.5 times the inner tube diameter of the straight tube portion, or more. Moreover, taking into consideration the mechanical strength of the  
15 bent portion, the inner tube diameter at the bent portion is preferably 2.5 times or less the inner tube diameter of the straight tube portion, and more preferably, 1.8 times or less.

According to this configuration, the coldest portions are formed at the bent portions of the bulb having straight tube portions with  
20 an external tube diameter of 12 to 20 mm, so that the desired coldest portions can be secured without reducing the length of the discharge path, further improving the lamp efficiency.

The above fluorescent lamp preferably lights at a tube wall load of  $0.05 \text{ W/cm}^2$  or higher.

25 The tube wall load means, herein, the lamp input electric power per inner surface area of the bulb, and the greater the tube



wall load is, greater the amount of the heat emitted is, so that the bulb temperature tends to be higher. Further, it is to be noted that the term of " inner surface area of the bulb" used herein does not mean the inner surface area of the entire bulb but rather means the inner surface area of the bulb at regions where the discharge path is formed.

In a case that the bulb temperature is high, the mercury vapor pressure within the bulb rises and exceeds the optimal temperature, and it is necessary to form the coldest portions in the bulb.

Particularly, in a case that the tube wall load is  $0.05 \text{ W/cm}^2$  or higher, experiment shows that the forming of the coldest portion according to the present invention makes the mercury vapor pressure appropriate and the lamp efficiency can be further improved. This advantage is manifested further markedly in cases that the tube wall load is  $0.1 \text{ W/cm}^2$  or higher.

With such a configuration, the fluorescent lamp lights at a tube wall load of  $0.05 \text{ W/cm}^2$  or higher, and the mercury vapor pressure is made appropriate and the lamp efficiency can be further improved.

According to the above fluorescent lamp, at the bent portions, the tip of one adjacent straight tube portion may be formed so as to extend and protrude in the axial direction of the straight tube portion over the connecting portion.

By forming the bent portions such that the tip of a straight-tube-shaped bulb protrudes over the connecting position of an adjacent straight-tube-shaped bulb, this protruding region

constitutes a non-discharge region of this protruding region, thus forming the coldest portion. Accordingly, a desired coldest portion can be formed simply by protruding the tip of the straight-tube-shaped bulb without forming the bent portion into special shape.

5 According to such a configuration, the coldest portion can be formed at the bent portion simply by protruding the tip of a straight-tube-shaped bulb, thereby facilitating the formation of the bent portion.

The present invention further provides a fluorescent lamp  
10 comprising:

a discharge vessel having a glass bulb formed by partially bending a glass tube having an external tube diameter of 12 to 20 mm and a tube length of 800 to 3000 mm so as to form a plurality of straight tube portions and bent portions, which are alternately  
15 adjacently arranged, within a same plane, such that both end portion provide straight tube portions so as to be adjacent one another so as to provide entirely a polygonal shape, the glass bulb being provided with a pair of sealed fine tubes for discharge extending from both end portions of the glass bulb, a phosphor layer  
20 formed on the inner surface side of the glass bulb, a pair of electrodes sealed on an inner side of both end portions of the glass bulb, and a discharge medium sealed within the glass bulb; and  
a base provided to both the end portions of the bulb.

According to this invention, since a discharge medium is  
25 sealed after exhausting from each of a pair of fine tubes, the exhausting is performed well even though the slender and long

discharge vessel having an outer tube diameter of 12 to 20 mm and a tube length of 800 to 3000 mm provides a polygonal shape. Thus, residual impure gasses in the discharge vessel can be reduced.

Consequently, the luminous flux maintenance factor of the

5 fluorescent lamp can be improved.

With the above fluorescent lamp, a part of at least one of the paired fine tubes is bent so that the pair of fine tubes extend approximately in parallel to each other.

With such a configuration, the manufacturing processes of the  
10 present invention will become easier. That is, according to the arrangement in which the tip portions of the paired fine tubes are parallel, the pair of fine tubes can be easily connected to a vacuum pump head, and also the manufacturing facilities can be simplified in construction. Further, the gas cleansing before exhaust or  
15 evacuation can be performed easily by using the paired fine tubes. Furthermore, the process is facilitated at the time of sealing in the discharge medium after the exhaust or exhaust.

The present invention further provides a method of manufacturing a fluorescent lamp of the structures mentioned above,  
20 which comprises the steps of:

forming a discharge vessel having a straight-tube-shaped glass bulb, in which a phosphor layer is disposed on an inner surface of a glass tube having an external tube diameter of 12 to 20 mm and a tube length of 800 to 3000 mm, and electrode mounts for supporting  
25 electrodes and having a pair of fine tubes are sealed at the end portions of the glass tube;

shaping the discharge vessel, in which the straight-tube-shaped glass bulb is partially heated to be softened and then bent so as to alternately form a plurality of tube portions so as to be adjacent to each other and bent portions within a same plane such that both the end portions constitute straight tube portions and are adjacent one another so as to provide an entirely polygonal shape;

exhausting the interior of the discharge vessel from each of the paired fine tubes extending from the end portions of the glass bulb following the discharge vessel shaping step and, subsequently, sealing in a discharge medium and then sealing off the fine tubes; and

disposing a base on both end portions of the discharge vessel.

In the above method, the exhausting/sealing step is a step for exhausting the interior of the discharge vessel from the pair of fine tubes extending from the ends of the glass bulb after the shaping step of the discharge vessel, and the sealing in the discharge medium and subsequently sealing off the fine tubes. In this process, the exhausting step is a step for performing the exhaust, i.e., exhaust, simultaneously from both ends of the discharge vessel through the pair of fine tubes. Inert gas cleansing may be performed in advance of the exhausting step. In this case, the cleansing can be performed through the pair of fine tubes.

The sealing of the discharge medium is performed by utilizing one or both of the paired tubes. Mercury vapor is sealed into the discharge vessel through the fine tubes in form of either one of pure mercury or amalgam.

The interior of the discharge vessel is evacuated, and then, the discharge medium is sealed therein. Subsequently, the paired fine tubes are sealed off by closing the valve of the tube connecting to the device for sealing the discharge medium and heating the middle portion of the fine tube by a gas burner. Thus, the heated glass portion is melted and cut off, and the molted tip portion invades into the fine tube, and is then hardened, due to the low pressure within the discharge vessel and hardens. Consequently, the structure, in which the tip ends of the paired fine tubes have the inwardly protruding inner surfaces, which is one subject feature of the present invention, can be provided.

As mentioned above, according to the present invention, since the exhaust of the discharge vessel is simultaneously performed through the pair of fine tubes extending from both ends of the glass bulb, the exhaust is performed sufficiently surely even in a case that the discharge vessel has a polygonal shape. Accordingly, the luminous flux maintenance factor of the obtained fluorescent lamp can be improved.

In the fluorescent lamp mentioned above, the pair of fine tubes preferably extend in the horizontal direction to the mutually opposing bulb end portion sides and then curved at the curved portion with a radius of curvature of 15 to 30 mm, through which the tip end portions stand upward.

The curvature radius of the curved portions of the pair of fine tubes is 15 to 30 mm, so that the mercury sealing medium such as mercury or amalgam inserted from the fine tubes smoothly moves

through the fine tubes by its own weight.

Thus, the mercury can be sealed into the airtight container speedily and surely, and the efficiency of the sealing treatment can be improved.

5 Further, in the case where the curvature radius of the curved outer end portions of the paired fine tubes is smaller than 15 mm, the curving degree of this curved portion becomes sharply closer to a right angle, leading to a problem that the difficulty in the insertion of the mercury into the fine tube outer end portions increases  
10 further.

On the other hand, in the case where the curvature radius of the curved portions exceeds 30 mm, the erecting angle of the curved portions is conversely a blunt angle. Accordingly, since there increases the amount of enlargement of the erected portions of the  
15 fine tubes enlarging toward the sealing end side of the airtight container, which may result in the enlargement of the gap between the paired sealing end portions which do not emit light, inviting a problem of reducing the lamp efficiency.

However, according to the present invention, since the curved  
20 portions of the fine tubes have a curvature radius of 15 to 30 mm, such problems can be avoided beforehand.

In addition, according to the fluorescent lamp of the present invention, it is desirable that the center axes of horizontal portions of the paired fine tubes extending in the horizontal directions toward  
25 the mutually opposing bulb end portion sides are arranged so as to be offset to each other.

According to this structure, the horizontal portions of the outer end portions of the paired fine tubes (exhaust tubes) are configured such that the center axes thereof are mutually offset so as to extend near the sealing end portion without abutting against the horizontal portions of the outer end portions of the paired fine tubes with each other.

Accordingly, the gap between the pair of sealing end portions, which is a dark portion, can be prevented from enlarging while lengthening the length of the horizontal portions of the pair of fine tubes, thus allowing the radius of curvature of the curved portions to be easily made larger without increasing the dark portion.

Further, the present invention also provides a lighting apparatus, which comprises: a lighting apparatus main unit; a fluorescent lamp disposed in the lighting apparatus main unit and having the structure mentioned hereinbefore; and a high-frequency lighting circuit which lights the fluorescent lamp by applying high-frequency voltage of 10 kHz or higher thereto.

In this invention, the term "lighting apparatus" is a broad concept encompassing all devices using the light emitted from the fluorescent lamp stipulated in claims 1 to 3, including examples such as lighting fixtures, marker lamps, display lamps, advertising lamps, and so forth. Furthermore, the term "lighting apparatus main unit" means the remainder of the lighting apparatus with the fluorescent lamp and the high-frequency lighting circuit removed therefrom. The lighting apparatus is permitted to have a configuration in which the fluorescent lamp lights in a space closed

by members such as a light-transmitting globe or shade, for example.

However, there may be adopted a configuration in which the fluorescent lamp lights in a state exposed externally. Moreover, the high-frequency lighting circuit is circuit means for lighting the

5 fluorescent lamp with high-frequency, and switching means for the high-frequency output may be provided as desired. The switching means may have a configuration enabling the switching between a low-power mode for high-efficiency lighting of the fluorescent lamp and a high-power mode for high-output lighting of the fluorescent  
10 lamp, or a configuration in which these modes are continuously switched therebetween. The switching of such switching means for the lighting circuit adjusts the lighting power of the fluorescent lamp.

The fluorescent lamp is attached according to the shape of the  
15 lighting fixture main unit or optical properties of the lighting fixture, and multiple fluorescent lamps of the same shape or different shapes are mounted to the fixture main unit within the same plane or disposed at different heights.

Consequently, according to the present invention, high-  
20 frequency lighting of the above fluorescent lamp enables a lighting apparatus which is lightened with the high efficiency to be obtained.

#### Brief Description of The Drawings

Fig. 1 is a front view of a fluorescent lamp according to a first  
25 embodiment of the present invention.

Fig. 2 (a), (b), (c), and (d) are schematic illustrations explaining



the manufacturing process of the fluorescent lamp shown in Fig. 1.

Fig. 3 is a front view of a fluorescent lamp according to a third embodiment of the present invention.

Fig. 4 is a front view of a fluorescent lamp according to a  
5 fourth embodiment of the present invention.

Fig. 5 is a front view of a fluorescent lamp according to a fifth embodiment of the present invention.

Fig. 6 is a front view, partially in section, illustrating the principal components of the fifth embodiment.

10 Fig. 7 is a graph showing mercury vapor pressure characteristics of main amalgam in the fifth embodiment together with those of a comparative example.

Fig. 8 is a graph showing the mercury vapor characteristics of main amalgam in a sixth embodiment of the present invention  
15 together with those of a comparative example.

Fig. 9 is a front view illustrating a positional relation between a glass bulb and electrodes in a fluorescent lamp according to a seventh embodiment of the present invention together with those of a conventional ring-shaped fluorescent lamp.

20 Fig. 10 is a view showing an essential portion of a fluorescent lamp, in an enlarged scale, according to an eighth embodiment of the present invention.

Fig. 11 is an end view at a cutaway portion taken along the line XI-XI in Fig. 10.

25 Fig. 12 is also an end view illustrating a modification of the eighth embodiment.

Fig. 13 is a front view of a fluorescent lamp according to a ninth embodiment of the present invention.

Fig. 14 is an enlarged view of a bent portion shown in Fig. 13.

Fig. 15(a) is a front view illustrating a lighting apparatus of a tenth embodiment of the present invention, and Fig. (b) is a side view thereof.

Fig. 16 is a front view of a fluorescent lamp according to an eleventh embodiment of the present invention.

Fig. 17 (a) and (b) are cross-sectional enlarged views showing essential portions at a portion taken along the line XVII-XVII in Fig. 16.

Fig. 18 is an enlarged view of an essential portion showing a mutual relation between the burning width of a bent-portion-formation preordination portion of a straight-tube-shaped glass bulb and the bending width thereof.

Fig. 19 is a front view of a fluorescent lamp according to a twelfth embodiment of the present invention.

Fig. 20 is a front view of a fluorescent lamp according to a first modification of the embodiment shown in Fig. 19.

Fig. 21 is a front view of a fluorescent lamp according to a third modification of the embodiment shown in Fig. 19.

Fig. 22(a) is a front view of a fluorescent lamp according to a thirteenth embodiment of the present invention, and (b) is a partial enlarged view of an electrode sealing end portion of the fluorescent lamp of Fig. 22(a).

Fig. 23 (a) through (e) are front views of fluorescent lamps

according to first through fifth modifications of the thirteenth embodiment of the present invention, respectively.

Fig. 24 is a schematic plan view illustrating a lighting fixture according to a fourteenth embodiment of the present invention.

5 Fig. 25 is a front view of a wire lamp in a state with the base removed, illustrating a partially enlarged cross-sectional view of a fluorescent lamp according to a fifteenth embodiment of the present invention.

10 Fig. 26 is an enlarged cross-sectional view of the tube end portion of the fluorescent lamp shown in Fig. 25.

Fig. 27 (a), (b), (c), (d), and (e) are schematic illustrations representing steps for shaping the discharge vessel of the fluorescent lamp shown in Fig. 25.

15 Fig. 28(a) is a schematic view, partially cutaway view, of a discharge vessel before exhaust, according to a sixteenth embodiment of the present invention, and (b) is a side view thereof.

20 Fig. 29(a) is a front view of a wire lamp in a state with the base removed, according to a seventeenth embodiment of the present invention, and (b) is a front view of a wire lamp according to an eighteenth embodiment of the present invention.

Fig. 30 is a side view, in an enlarged scale, of a pair of fine tubes and the periphery thereof, according to a nineteenth embodiment of the present invention.

Fig. 31 is a plan view of Fig. 30.

25 Fig. 32 is a view illustrating the angle of inclination of the pair of fine tubes shown in Fig. 30 and Fig. 31.

[Reference Numerals]

2, 102, 112, 202 --- glass bulb, 2a, 102a --- straight-tube bulb,  
2b, 102b, 202b --- straight-tube portion, 2c, 101c, 201c --- bent  
portion, 2d, 102d, 202d --- end portion, 1e, 201g, 201h --- fine tube,  
5 1f --- lead wire, 3 --- protective layer, 4 --- phosphor layer, 5, 105,  
205 --- electrode, DV --- discharge vessel, FL ---fluorescent lamp, H  
--- flare stem, M --- electrode mount

Best Mode for Carrying Out The Invention

10 The following is a description of an embodiment of the ring-  
shaped fluorescent lamp and a lighting apparatus according to the  
present embodiment, with reference to the drawings.

Fig. 1 and Fig. 2 illustrate a first embodiment of the present  
invention, Fig. 1 being a front view of the fluorescent lamp and Fig.  
15 2 includes illustrations for explaining the manufacturing process of  
the fluorescent lamp shown in Fig. 1.

In the drawings, reference numeral 1 denotes a fluorescent  
lamp having a discharge vessel DV and a base 6. The discharge  
vessel DV is composed of a rectangular glass bulb 2 provided with  
20 the straight portions forming a substantially quadrate shape and  
having the following structure. That is, a discharge medium  
including a noble gas and mercury is sealed in the glass bulb. The  
noble gas is argon (Ar) gas, sealed at a pressure of approximately  
320 Pa. The other known discharge agents such as neon, krypton,  
25 xenon, etc., may be used as the noble gas in addition to or instead  
of the argon.

A protective layer 3 formed of fine particles of metal oxide is formed on the inner face of the glass bulb 2, and a phosphor layer 4 made up of fine particles of a three-wavelength emission type fluorescent substance is formed on the inner surface of the protective layer 3. The phosphor layer 4 is preferably coated with fine particles of the 3-wavelength emission fluorescent substance. The phosphor layer 4 has a correlated color temperature of 5000 K, the amount thereof being in the range of 4.0 to 7.5 mg/cm<sup>2</sup>, preferably within the range of 4.0 to 6.0 mg/cm<sup>2</sup>, and is formed in a film having a thickness of 20 μm by way of a drying/baking process. Further, the coating amount of the protective layer is 0.6 to 0.8 mg/cm<sup>2</sup>.

Although it is possible to compose the phosphor forming the phosphor layer 4 with a known fluorescent substance such as the 3-wavelength emission fluorescent substance, halo-phosphate fluorescent substance, or the like, it is preferable to use the 3-wavelength emission fluorescent substance in terms of the perspective of emission efficiency.

Examples of such 3-wavelength emission fluorescent substance include, though not limited to, BaMg<sub>2</sub>Al<sub>16</sub>O<sub>27</sub>:Eu<sup>2+</sup> as a blue phosphor having an emission peak wavelength around 450 nm, (La, Ce, Tb)PO<sub>4</sub> as a green phosphor having an emission peak wavelength around 540 nm, Y<sub>2</sub>O<sub>3</sub>:Eu<sup>3+</sup> as a red phosphor having an emission peak wavelength around 610 nm, and so forth.

Further, it is to be noted that, as the fine particles of metal oxide used for the protective layer 3, known ones such as alumina

( $\text{Al}_2\text{O}_3$ ) or silica ( $\text{SiO}_2$ ) having a thickness of 0.5  $\mu\text{m}$  or more may be preferably utilized.

In addition, a protective layer may be formed to have a thickness of approximately 10 to 20  $\mu\text{m}$  by using strontium phosphate ( $\text{Sr}_2\text{P}_2\text{O}_7$ ) fine particles with an average grain diameter of approximately 2.5  $\mu\text{m}$ .

The glass bulb 2 has four straight tube portions 2b and three bent portions 2c, and the four straight tube portions 2b are connected within substantially the same plane so as to form the sides of a quadrate shape. Further, it is desirable for the glass bulb 2 to have a length L, one side thereof, preferably 200 mm or longer, and in this embodiment, the length L is approximately 300 mm. Both end portions 2d of the glass bulb 2 are disposed in close proximity, and filament electrodes 5 and 5 formed of triple coils coated with an emitter substance are each sealed at the end portions 2d. The electrodes 5 and 5 supported by a pair of lead wires preliminarily sealed to flare stems, not shown so as to provide electrode mounts, and the filament electrodes 5 and 5 are sealed within the bulb by the electrode mounts sealed in both the end portions 2d of the glass bulb 2. An exhaust fine tube 2f is attached to one flare stem, and amalgam 2g for controlling mercury vapor pressure is stored within this fine tube 2f.

The outer tube diameter of the straight tube portion 2b is 12 to 20 mm, the thickness of the wall of the tube is 0.8 to 1.5 mm, preferably 0.8 to 1.2 mm, and in the case of this embodiment, the inner tube diameter is approximately 16 mm and the thickness of the

wall of the tube is approximately 1.2 mm. The interiors of the respective straight tube portions 2b are communicated via the bent portions 2c so that a single discharge path is formed so as to surround the center of the quadrate shape formed by the straight tube portions 2b between the pair of electrodes 5 and 5.

The base 6 is mounted on the end portions 2d and 2d of the glass bulb 2 so as to straddle the end portions 2d and 2d. The base 6 is provided with a power supply member 6a made up of four pins electrically connected to the pair of electrodes 5 and 5. The fluorescent lamp 1 has three bent portions 2c formed at three diagonal positions of the quadrate shape formed by the straight tube portions 2b of the glass bulb 2, and the base 6 is disposed at the remaining one diagonal position.

The bent portions 2c have approximately the same cross-sectional shape as that of the straight tube portions 2b. The cross-sectional shape of the bent portion 2c may be approximately triangular or square shape. In a case that the bent portion 2c has a shape protruding outward, the discharge path is formed on the inner side. This matter means that the non-discharge region is great, and optimal coldest portions with high cooling effects can be realized, and temperature characteristics can be improved even with no use of the amalgam for controlling the mercury vapor pressure.

Fig. 2(a) to (d) are views explaining the manufacturing method of the glass bulb 2 for the fluorescent lamp 1 of the structure mentioned above. In the manufacturing method of this glass bulb 2a, as shown in Fig. 2(a), first, a single circular-tube straight-tube-

shaped bulb 2a provided with the protective layer 3 and the phosphor layer 4 which were preliminarily formed, and the electrodes 5 and 5 are mounted within the bulb 2 by way of flare stems, not shown, with an exhaust tube 2f at one of both end portions 2d and 2d for introducing the pair of leads.

The pair of electrodes 5 and 5 are composed of hot cathode electrodes, which has a filament coated with an emitter substance, but may be substituted with other electrodes. Further, in a case where high-output lighting performance is required for the lamp, a triple coil is preferably used for the hot cathode electrodes. In addition, the leads supporting the electrodes 5 and 5 may be sealed and supported by members such as a button stem, bead stem, pinch seal, or the like. Further, the stem or the like may be attached thereto a fine tube for exhausting or for storing a mercury alloy.

The entire length of the straight-tube-shaped bulb 2a is of 1200 mm and includes three bent-portion-formation preordination portions 2e (i.e., portions 2e to be formed as bent portions later). The lengths  $l_1$ ,  $l_2$ , and  $l_3$ , of the preordination portions 2e are approximately 90 mm, respectively, and the total length of the three preordination portions 2e is 270 mm, which is approximately 23% of the entire length of the straight-tube-shaped bulb 2a.

As shown in Fig. 2(a), the bent-portion-formation preordination portion 2e is first heated and softened with a gas burner B, and as shown in Fig. 2(b), a bending working is performed so that the angle between the adjacent straight tube portions 2b constitutes approximately of  $90^\circ$ , and thereafter, a first bent portion 2c is



formed to a predetermined shape through a molding process or like. Subsequently, the bent-portion-formation preordination portion 2e adjacent (continuous) to the first bent portion 2c is heated and softened with the gas burner B and subjected to the bending and molding working, thereby forming the second bent portion 2c as shown in Fig. 2(c). Finally, the bent-portion-formation preordination portion 2e adjacent to the second bent portion 2c is heated and softened with the gas burner B and subjected to the bending and molding working, thereby forming the third bent portion 2c as shown in Fig. 2(d). The bulb is then evacuated from the exhaust tube 2f, mercury is sealed therein, thus completing the glass bulb 2.

Although the bent portions 2c are formed by the bending working, it is not necessary to excessively heat the portions of the straight-tube-shaped bulb 2a other than the bent-portion-formation preordination portions 2e, so that even in the case of applying the phosphor layer 4 before the formation of the bent portions 2c, thermal deterioration of the fluorescent substance does not readily occur, and yielding the advantage that the luminous flux maintenance factor is markedly improved. Such advantages are markedly manifested in the case that the total length of the bent-portion-formation preordination portions 2e is 50% or less, preferably 30% or less, and optimally 20% or less, with respect to the entire length of the straight-tube-shaped bulb 2a.

The fluorescent lamp 1 may take the following dimensions. For the fluorescent lamp 1 equivalent to an article of conventional 30 W

type ring-shaped fluorescent lamp, the entire length L of the glass bulb 2 is formed to be 225 mm, the greatest width on the inner side is 192 mm, the outer tube diameter is 16 mm, and thickness of the wall of the glass bulb 2 is 1.0 mm. The rated lamp power of the fluorescent lamp is 20 W, and the high-output-property lamp power is 27 W when the lamp is lightened. For the fluorescent lamp 1 equivalent to an article of conventional 32 W type ring-shaped fluorescent lamp, the entire length L of the glass bulb 2 is formed to be 299 mm, the greatest width on the inner side is 267 mm, the outer tube diameter is 16 mm, and thickness of the wall of the glass bulb 2 is 1.0 mm. The rated lamp power of the fluorescent lamp is 27 W, and the high-output-property lamp power is 38 W when the lamp is lightened. For the fluorescent lamp 1 equivalent to an article of conventional 40 W type ring-shaped fluorescent lamp, the entire length L of the glass bulb 2 is formed to be 373 mm, the greatest width on the inner side is 341 mm, the outer tube diameter is 16 mm, and thickness of the walls of the glass bulb 2 is 1.0 mm. The rated lamp power of the fluorescent lamp is 34 W, and the high-output-property lamp power is 48 W when the lamp is lightened.

The fluorescent lamp of this embodiment will operates as follows. The fluorescent lamp 1 is supplied with high-frequency electric power input through the power supply member 6a of the base 6 and is lightened through the low-pressure mercury vapor discharging in the bulb 2. The fluorescent lamp 1 is lightened with the lamp input power of 20 W or more, lamp current of 200 mA or more, tube wall load of  $0.05 \text{ W/cm}^2$  or higher, and the lamp

efficiency of 50 lm/W or more. Further, the lamp current density, as the lamp current per cross-sectional area of the straight tube portion 2b, is  $75 \text{ mA/cm}^2$  or higher. In the case of the present embodiment, the lamp input power is 50W, the lamp current is 380  
5 mA, and the lamp efficiency is 90 lm/W.

Amalgam may be sealed in the bulb 2. For example, amalgam such as zinc-mercury may be sealed in order to seal in a predetermined amount of mercury. By enclosing the amalgam for controlling the mercury vapor in the bulb, the ambient temperature  
10 becomes relatively high and the fluorescent lamp is lightened in the optimal state.

The amalgam may take any shape, such as pellet, cylinder, plate, or the like. The amalgam is stored in a fine tube arranged to on a stem sealed to the end of the bulb or in side the bulb 2. The  
15 amalgam is fixed to or stored in one of the positions mentioned above by means of fusion, mechanical holding or the like. Furthermore, the amalgam may be stored in the bulb to be movable therein.

At the time of lighting the fluorescent lamp 1, the temperature  
20 of the bulb 2 rises to around  $80^\circ\text{C}$ . In this embodiment, however, bismuth (Bi) - tin (Sn) - lead (Pb) amalgam is stored in the fine tube 2f, so that the vapor pressure in the bulb is controlled to a proper value based on the pressure characteristics of the mercury vapor of the amalgam, and accordingly, the lamp can be lightened with high  
25 efficiency.

Furthermore, although in the present embodiment, the glass

bulb 2 is formed by partially bending the single straight-tube-shaped bulb 2a, in an alternation, it may be possible to connect the ends of two bulbs bent into L-shapes so as to form a single bent portion and form the glass bulb 2.

5        The glass bulb 2 is formed of a soft glass such as soda-lime glass, lead glass or the like, but hard glass such as borosilicate glass or quartz glass may be used as well. In addition, there may be used a glass which contains essentially no lead component with inclusion of sodium oxide of 1.0 percent by mass or less and at a  
10       softening temperature of 720°C or lower. The disclosure of "contains essentially no lead component" means that it is permissible to include a trace as an impurity preferably of 0.1 percent by mass or less. Of course, it is most preferred that the glass does not contain no lead component. The case of including  
15       sodium oxide of 0.1 mass % or less includes a case of no sodium oxide. Also, the reason that the inclusion of sodium oxide has been stipulated to 0.1 mass % or less is that deposition of the sodium component on the inner surface of the glass bulb 2 affects the light output of the fluorescent lamp 1 if the inclusion thereof exceeds the  
20       above value. In the glass containing substantially no lead, in which the glass has inclusion of sodium oxide of 1.0 mass % and a softening temperature of 720°C or lower, the amounts of  $K_2O$  and  $Li_2O$ , and the amounts of  $CaO$ ,  $MgO$ ,  $BaO$  and  $SrO$  can be adjusted in contents. Herein, the softening temperature is a temperature  
25       wherein the viscosity  $\eta$  of glass =  $10^{7.65}$  dPa·s.

      In the event that the amount of sodium oxide in the glass bulb

2 exceeds 0.1 mass %, a great amount of sodium is deposited on the inner surface of the glass bulb 2 during the lighting of the lamp, as an alkali component. In this case of depositing of the sodium on the inner surface of the glass bulb 2, a problem that the sodium may  
5 react with the mercury vapor sealed in the glass bulb 2, the glass bulb 2 may be colored and transmissivity of visible light is reduced, or the sodium may react with the phosphor in the phosphor layer 4, deteriorating the phosphor, and reducing the output power of visible light. Particularly, since the conventional soda lime glass contains  
10 15 to 17 mass % sodium oxide, such deterioration of the visible light output will be remarkably observed.

Accordingly, by applying the phosphor to the straight-tube-shaped bulb 2a formed of a glass with an inclusion of sodium oxide of the amount of 0.1 mass % or less at a softening temperature of  
15 720°C or lower, 692°C for example, and then forming the bent portions later, the amount of sodium to be deposited on the inner surface of the bulb could be drastically reduced, and in addition, the deterioration of visible light output due to the sodium reaction could be also suppressed. Furthermore, since the softening temperature  
20 is 720°C or lower, the heating temperature at the time of forming the bent portions can be kept low, and hence, thermal deterioration of the surrounding phosphor could be reduced with increased light output performance.

The composition of the glass bulb according to the present  
25 embodiment is as follows, and the softening temperature is 692°C.

SiO<sub>2</sub>: 65.0 mass %, Al<sub>2</sub>O<sub>3</sub>: 4.0 mass %, Na<sub>2</sub>O: 0.05 mass %,

K<sub>2</sub>O: 11.0 mass %, Li<sub>2</sub>O<sub>3</sub>: 2.8 mass %, CaO: 2.0 mass %, MgO: 1.4 mass %, SrO: 5.0 mass %, BaO: 8.5 mass %, SO<sub>3</sub>: 0.15 mass %, B<sub>2</sub>O<sub>3</sub>: 0 mass %, Sb<sub>2</sub>O<sub>3</sub>: 0 mass %, Fe<sub>2</sub>O<sub>3</sub>: 0.03 mass %, others: 0.17 mass %.

5        Hereunder, a second embodiment of the present invention will be described. In this second embodiment, the metal oxide constituting the protective layer 3 has fine particles of  $\gamma$  (gamma) alumina with an average grain diameter of approximately 5.0 to 50 nm, the surface area is 80m<sup>2</sup>/g or more, and the amount of fine  
10 particles applied per surface area in the bulb is 0.01 to 0.1 mg/cm<sup>2</sup>.

      In the case of the second embodiment, even if the amount of protective layer 3 applied is reduced and the film thickness thereof is also reduced, the straight tube portions 2b are essentially not stretched, and thermal deterioration of the phosphor layer 4 of the  
15 straight tube portions 2b in the bent portion forming step is small. Moreover, since the thickness of the protective layer 3 is small, the functions of the protective layer 3 can be sufficiently exhibited while suppressing the causing of the cracking at the bent portions 2c.

      Furthermore, the specific surface of the fine particles is 80m<sup>2</sup>/g or  
20 more, so the protective layer 3 is of an extremely compact structure, so alkali components deposited from the bulb 2 and mercury and the like are blocked by the protective layer 3, thereby allowing deterioration of the phosphor layer 4 over time and coloring of the bulb 2 to be suppressed effectively.

25        Fig. 3 is a front view illustrating a fluorescent lamp 1A of the third embodiment of the present invention. The present

embodiment is the same as with the first embodiment except that the quadrate glass bulb 2 is composed of five straight tube portions 2b and four bent portions 2c formed in the diagonal directions thereof, and the base 6 positioned at the approximate central portion of one side of the bulb 2.

Fig. 4 is a front view illustrating a fluorescent lamp 1B of the fourth embodiment of the present invention. The present embodiment has a base 6B provided so as to bridge the end portions 2d and 2d of the glass bulb 2 and the straight tube portion 2b on the opposing side. The base pins 6a serving as power supplying portions is provided at the center position of the rectangular shape of the bulb 2. Furthermore, a lamp holding mechanism to be mounted to a lamp holder of a lighting apparatus, not shown, side is provided near the power supplying member such that electrical connection is established at the same time of mounting the lamp to the lighting apparatus. By forming the base 6B in this way so as to bridge the two opposing sides of the square shape, the bulb 2 can be more stably supported and the attaching strength can be improved as well as improvement in the strength of the bulb 2 itself. In addition, by arranging the power supplying member to the approximate center of the square shape, the bulb 2 can be improved in the balance of the lamp at the time of mounting thereof, thereby facilitating replacement working thereof.

Fig. 5 through Fig. 7 illustrate a fluorescent lamp 1C which is a fifth embodiment of the present invention, in which Fig. 5 is a front view, Fig. 6 is a front view, partially in section, illustrating an

arrangement of an essential portion, and Fig. 7 is a graph representing the mercury vapor characteristics of the main amalgam together with comparative examples thereof.

The present embodiment differs from the above described  
5      embodiments in that the inner diameter of the bent portion 2c of the glass bulb 2 is set to a predetermined dimension, that the amalgam 2g having predetermined characteristics of the mercury vapor is used, and that the length of the exhausting fine tube is set within a predetermined range.

10      That is, the inner diameter of the bent portion 2c of the glass bulb 2 is set to be within the range of 0.6 to 1.0 of the inner diameter of the straight tube portions 2b, i.e., 0.86 times in the drawing, by shaping the bent portion by using a mold at the time of thermally softening and bending the preordination portions for the  
15      bent portions 2c of the glass bulb 2. Furthermore, the protrusion length of the exhausting fin tube 2f extending externally from a stem 2h at one end of the glass bulb 2 is 10 mm or longer, with a coldest portion formed at the tip thereof. Further, a protective layer existing between the glass bulb 2 and the phosphor layer 3 is not  
20      shown in the drawing.

The inner diameter of the bent portion 2c is measured at the cross-section of the bent portion 2c. If the cross-sectional shape of the bent portion 2c is a non-circle, the inner diameter is determined at a portion having the minimum tube diameter. In a case of the  
25      inner diameter of the bent portion 2c being less than 0.6 of that of the straight tube portion, the temperature of the bent portion 2c



risers. However, this is not desirable because the arc is squeezed at the bent portion 2c, resulting in the rising of the lamp voltage, and hence, the lamp power input becomes excessive and injection of mercury to the phosphor layer 4 increases, which finally leads to earlier deterioration of the phosphor layer. Furthermore, if the inner diameter of the bent portion 2c exceeds 1.0 times that of the straight tube portion, since the temperature of the bent portion 2c drops and the coldest portion is readily formed thereat, thus being not advantageous and desirable. On the other hand, by setting the inner diameter of the bent portion 2c of the bulb to be within the range of 0.6 to 1.0 times the inner diameter of the straight bulb portion 2b, the temperature of the bent portion 2c becomes substantially the same as the temperature of the straight tube portion 2b.

As shown in Fig. 6, the amalgam is formed of a main amalgam 2g and an auxiliary amalgam 2i. The main amalgam 2g contains, in terms of mass ratio, 40 to 50% Bi, 15 to 35% Pb, 15 to 40% Sn, and 6% or more Hg, and mercury vapor is introduced into the interior of the glass bulb 2 to be sealed and detained in the exhausting fine tube 2f. In addition, the main amalgam 2g includes 9 mass % of mercury in the above component range and has the pressure characteristics of the mercury vapor shown in Fig. 7.

The auxiliary amalgam 2i is composed of In or Au deposited on a stainless steel substrate and is disposed by welding the substrate at a position near the electrode 5 of a power source side lead-in wire 2j at the time of lighting.

Fig. 8 is a graph illustrating the mercury vapor characteristics of the main amalgam in a fluorescent lamp according to the sixth embodiment of the present invention together with a comparative example.

5 In this embodiment, the composition of the main amalgam 2g differs from that in the fifth embodiment, and that is, the main amalgam 2g contains, in terms of mass ratio, 50 to 60% Bi, 45 to 50% Pb, 0 to 3% In, and 3 to 5% Hg. Furthermore, the main amalgam 2g exhibits changes in the pressure characteristics of the  
10 mercury vapor in accordance with the inclusion amount of In such as shown in the drawing.

It may be possible for the main amalgam 2g to be fused and fixed in a ring-shaped molding portion to be formed to the end surface of the bulb by heating the end portion of the bulb and or  
15 forming a neck portion on the way of the fine tube so as not to fall down the main amalgam 2g in the fine tube.

Furthermore, it is desirable that the main amalgam 2g has the mercury vapor pressure within the range of approximately 0.13 to 1.1 Pa when the temperature is 50°C at the portion of the bulb 2  
20 close thereto or at the outer surface of the fine tube, and preferably, within the range of approximately 1.2 to 1.3 Pa at the temperature of 100°C at these portions.

Fig. 9 is a front view showing an essential portion of the fluorescent lamp of this embodiment and illustrating the positional  
25 relation between the glass bulb and electrodes of the a fluorescent lamp of this seventh embodiment together with those of a

conventional ring-shaped fluorescent lamp (left side view in Fig. 9) for comparison.

In this embodiment, instead of the mercury vapor pressure controlling amalgam, the electrode 5, having its height  $H_M$ , disposed on the tube end portion side of the exhaust side, which is set to be within the range of 30 to 50 mm, 40 mm for example, so that the most cooled portion is formed at the tube edge portion. Further, in the present invention, the electrode 5 is positioned at a portion facing the straight tube portion 2b of the glass bulb 2, so that the distance between the inner surface of the glass bulb and the electrode 5 becomes greater than that of the ring-shaped fluorescent lamp, and therefore, as can be seen from Fig. 9, the electrode 5 does not easily come into contact with the phosphor layer of the tube wall. Further, in Fig. 9, reference numeral 2g denotes zinc amalgam for sealing in a predetermined amount of mercury, with the phosphor layer being omitted from the drawing for the sake of convenience in description.

Moreover, since the most cooled portion of the glass bulb 2 has the large height, the coldest portion of the glass bulb 2 is formed at a ring-shaped mold portion 2k (near the amalgam 2g) near the sealing portion at the tube end side of the exhaust side, or at the front end portion of the excavating fine tube 2f.

Fig. 10 is an enlarged front view of the base 6 of a fluorescent lamp 1D together with its surroundings of the eighth embodiment of the present invention, and Fig. 11 is an end taken along the line XI-XI in Fig. 10.

This embodiment differs from the embodiments mentioned hereinabove in the provision of a turning motion restricting member for preventing a base 6D, formed of plastic material, for example, to be fitted externally to both axial-direction end portions 2d and 2d of the glass bulb 2 in which the pair of electrodes 5 and 5 are sealed, from turning about the tube axis with respect both the end portions 2d and 2d of the glass bulb 2.

That is, in the fluorescent lamp 1D shown in Fig. 10, the pair of electrodes 5 and 5 are sealed in the both axial end portions 2d and 2d of the glass bulb 2, a pair of lead-in wires 2j and 2j connected to both the ends of the electrodes 5 are extended from both the end portions 2d and 2d of the glass bulb 2 in an airtight manner, and the front portions of the outer leads 2ja and 2ja, as the external ends thereof, are fixed to the inner front portions of base pins 6a of the base 6D.

The glass bulb 2 has both the end portions 2d and 2d, from which the pair of outer leads 2ja and 2ja externally extend in an airtight manner, pressed flat into pinch seal portions 2p, thereby sealing the lead-in wire 2j in an airtight manner, and the pinch seal portions 2p are shaped by molding into flattened shapes.

As shown in Fig. 11, the base 6D has engaging protrusions 6x and 6y of the plastic base main unit 6b in form of a cylindrical member which is dividable into two parts, top and bottom, so as to be fitted from the external side to both side ends of the pinch seal portions 2p.

According to this arrangement, the base 6D can be prevented

from turning about the tube axis with respect to the glass bulb 2, thereby preventing the outer leads 2ja from breaking, the pair of outer leads 2ja and 2ja from contacting to each other, and a lighting circuit, not shown, from damaging due to short-circuiting and both  
5 the end portions 2d and 2d of the glass bulb.

That is, in the case where the base main unit turns with to the tube axis as like as the bases of conventional ring-shaped fluorescent lamps, since both the ends of the outer leads 2ja are fixed to each of the pinch seal portions 2p and the inner front end  
10 portion of the pin 6a of the base 6D, pulling or twisting of the outer leads 2ja by the turning of the base 6 may be caused, resulting in breakage thereof, damage to the pinch seal portions 2p. Conversely, the adjacent outer leads 2ja may come into contact one another and cause short-circuiting, thus damaging the lighting circuit.

15 However, according to the fluorescent lamp 1D of the present embodiment, the base main unit 6b can hardly be moved with respect to the glass bulb 2 due to the provision of the turn restricting member, so that the problems encountered in the prior art mentioned above to the base can be effectively solved.

20 Fig. 12 is a cross-sectional view of another modification of the turn restricting member of the base 6D. The turn restricting member permits the turning of the base 6D around the tube axis by 45° in the forward and reverse direction, with a plurality of outward-facing retaining protrusions 2m being protruded by means of glass  
25 frits or like on the outer peripheral surfaces of both the end portions 2d, approximately circular axial cross-sectional shape, with the

center angles thereof being approximately at right angles. In such modified example, it is not necessary to form the pinch seal portions 2p such as shown in Fig. 10 and can be utilized for the bulb end portions 2d using a flare stem such as illustrated to the right side in Fig. 9.

On the other hand, on the inner peripheral surface of a fitting hole 6cb of the base main body 6b, a pair of inward-facing retaining protrusions 6e and 6e protruding toward the center side of the fitting hole at an intermediate portion of the circumference between the pair of protrusions 2m adjacent in the circumferential direction of both edge portions 2m of the glass bulb are provided integrally in a standing manner at an opposing position in the diameter direction.

Accordingly, the base 6D turns  $45^\circ$  in the clockwise direction (forward direction) with respect to the glass bulb 2, and on the other hand, also turns  $45^\circ$  in the counter-clockwise direction (reverse direction). However, in this case, it is necessary to provide the outer leads 2ja and 2ja with a sufficient length so that the outer leads 2ja and 2ja will not be pulled and broken or the pinch seal portions 2p are not damaged at an occurrence of such turning, and it is also necessary to provide an element or like for preventing electrical connection between the pair of outer leads 2ja and 2ja.

According to this base 6D, the base 6D can rotate  $45^\circ$  in each of the forward and reverse directions with respect to the glass bulb 2 about the tube axis, so that a range capable of mounting the base to a power supplying socket fixed to the lighting apparatus body can be widened by rotating the base 6D after the fixing of the glass bulb 2 a

lamp holder of the lighting apparatus body. Further, it is to be noted that it is not necessary to limit the turning angle of the base 6D to 45° in each of the forward and reverse directions and can be suitably selected as occasion demands by appropriately changing the positions of the outward-facing retaining protrusions 2m and the inward-facing retaining protrusions 6e.

Fig. 13 is a front view of a fluorescent lamp 1E according to the ninth embodiment of the present invention, and Fig. 14 is an enlarged view of a bent portion thereof.

In this embodiment, in a case where the radius of curvature of the bent portion 2c of the glass bulb 2 is too small, the outer side of the bent portion 2c will stretch too much and become too thin and accordingly breaks readily. Thus, the embodiment is characterized by the feature in which the radius of curvature of the bent portion 2c and the thickness of the wall are stipulated to predetermined values, thereby improving the strength of the fluorescent lamp 1E.

As shown in Fig. 14, the bent portion 2c is formed such that the center O of curvature radius r1 of the inner side surface 2c1 and the center O of curvature radius r2 of the outer side surface 2c2 take substantially the same position. The inner side surface 2c1 of the bent portion 2c means the surface facing the center portion of an imaginary ring-shaped pane formed by the glass bulb 2, and the outer side surface 2c2 of the bent portion 2c means the surface position opposite by 180° from the inner side surface 2c1 at the bent portion 2c with the tube axis being the center therebetween (i.e., a surface facing the direction radially extending in parallel from the

central portion of a ring-shaped plane formed by the glass bulb 2 along this plane).

The curvature radii  $r_1$  and  $r_2$  are defined by curves formed at a position at which the inner and outer side surfaces  $2c_1$  and  $2c_2$  and an imaginary ring-shaped plane formed by the glass bulb intersect, and more conveniently, may be defined by the radius of curvature of the inner and outer outlines formed at the bent portion  $2c$  when observing the glass bulb from a direction perpendicular to the imaginary ring-shaped plane formed by the glass bulb 2. The optimal range for the curvature radius  $r_1$  is 10 to 30 mm, and the optimal range for the curvature radius  $r_2$  is 25 to 55 mm. On the other hand, in this embodiment, the curvature radius  $r_1$  is 15 mm and the curvature radius  $r_2$  is 31.5 mm. Further, for the sake of increasing the strength of the bent portion  $2c$ , the wall thickness  $t_2$  at the outer side face  $2c_2$  of the bent portion  $2c$  and the wall thickness  $t_1$  at the inner side face  $2c_1$  are made to be 0.5 mm or thicker through the bending working. In addition, in the case where the bulb 2 has an entirely long length  $L$ , the stress applied to the bent portions  $2c$  increases and the glass expanding ratio on the outer side of the glass will be increased, so that it is also necessary to increase the thickness at the bent portions after all so as to ensure the mechanical strength. Experimentation performed based on the above matters showed that the strength of the bent portions  $2c$  could be ensured by adjusting the wall thickness  $t_0$  of the straight tube portions so as to satisfy the equation of  $0.36 (L/r_1) \leq t_0 \leq 0.2 (L/r_1)$ .



Further, the tube diameter  $D_c$  of the bent portion 2c is formed to be approximately the same as the tube diameter  $D_b$  of the adjacent straight tube portion 2b. By thus forming the bent portion 2c, a visual recognition that the external view of the bent portion 2c of the ring-shaped bulb 2 is configured with a continuous curve from the straight tube portion 2b is given, so that the visual appearance of the light-emitting tube 2 can be improved.

Furthermore, since low-temperature portions at the time of lighting are not partially formed, it is hard that the coldest portion is readily formed and that black spots or stains due to aggregation are also readily formed at the bent portion 2c.

Further, the diameter  $D_c$  of the bent portion 2c and the tube diameter  $D_b$  of the straight tube portion 2b are both 16.5 mm in the lamp of this embodiment. The length  $l$  of the straight tube portion 2b is 237 mm.

According to this embodiment, the thickness of the wall at the bent portions 2c and the straight tube portions 2b are thus prescribed to the predetermined values, so that the shock withstanding strength of a level assumed to be encountered in normal use of the fluorescent lamp 1 can be ensured.

Fig. 15 illustrates a light apparatus according to the tenth embodiment of the present invention, wherein Fig. 15(a) is a front view and Fig. 15(b) is a side view thereof.

This embodiment relates to a lighting apparatus using one of the fluorescent lamps 1 and 1A through 1E (for example, fluorescent lamp 1) according to the above-described first to ninth embodiments.

The fluorescent lamp 1 is connected to a socket 11 of the apparatus (main) body 10 and is mounted to a lamp holder 12 formed of springs, having a shape following that of the bulb side. A pyramid-shaped white reflecting member 13 having a quadrangular pyramid shape is disposed at the center portion of the fluorescent lamp 1, 5 attached to the apparatus body 10. The reflecting member 13 is formed to have a hollow structure and stores the lighting device therein and so on. The reflecting member 13 may be directly attached to the lamp 1 side.

10 Since the lighting apparatus according to the present invention has the reflecting member 13 having a quadrangular pyramid shape disposed in the center of the square fluorescent lamp 1, the high reflection efficiency in the downward direction from the device fixture can be achieved and the lighting efficiency can also be 15 improved.

Fig. 16 and Fig. 17 illustrate an eleventh embodiment of the present invention, in which Fig. 16 is a front view of a fluorescent lamp, and Fig. 17 (a) and (b) are cross-sectional views of an essential portion thereof in an enlarged scale in a section taken 20 along the line XVII-XVII in Fig. 16.

In the drawings, reference numeral 101A denotes a fluorescent lamp having a rectangular glass bulb 102 constituted substantially in the quadrate shape by straight portions. A discharge medium composed of noble gas and mercury are sealed in the glass bulb 102. 25 The noble gas is argon (Ar) gas sealed in at a pressure of approximately 320 Pa.

A protective layer 103 approximately 1.0  $\mu\text{m}$  thick is formed, on the inner surface of the glass bulb 102, of alumina ( $\text{Al}_2\text{O}_3$ ) fine particles serving as metal oxide fine particles, and a phosphor layer 104 is formed, on the inner surface of this protective layer 103, of fine particles of the 3-wavelength emission phosphor. The phosphor layer 104 is formed of the 3-wavelength emission phosphor fine particles with a correlated color temperature of 5000 K, which is applied with the amount in a range of 4.0 to 6.0  $\text{mg}/\text{cm}^2$ , and then formed so as to have a thickness of 20  $\mu\text{m}$  by way of drying and sintering process.

The glass bulb 102 has a circular cross-sectional shape with four straight tube portions 102b and three bent portions 102c so that the four straight tube portions 102b are continuously arranged within the same plane so as to form the sides of the quadrangle shape. In general it is preferred that the one side length  $l$  of the glass bulb 102 is 200 mm or longer, and in this embodiment, the length  $l$  is approximately 300 mm. Both end portions 102d of the glass bulb 102 are disposed in close proximity, and filament electrodes 105, 105 formed of triple coils coated with an emitter substance are sealed at both end portions 102d, respectively.

It is generally preferred that the inner tube diameter of the straight tube portion 102b is 12 to 20 mm, the thickness of the wall of the tube is 0.8 to 1.5 mm, and in this embodiment, the inner tube diameter is approximately 16 mm, and the thickness of the wall of the tube is approximately 1.2 mm. The interiors of the respective straight tube portions 102b are communicated with each other

through the bent portions 102c in a manner that a single discharge path is formed so as to surround the center of the general quadrate shape formed by the straight tube portions 102b between the pair of electrodes 105 and 105.

5 A base 106 is mounted on both end portions 102d and 102d of the glass bulb 102 so as to straddle both the end portions 102d and 102d. The base 106 has a power supply member 106a formed from four pins electrically connected to the pair of electrodes 105 and 105. The fluorescent lamp 101 has three bent portions 102c formed at  
10 portions on the diagonal line of the quadrate shape, and the base 106 is disposed at the other remaining one portion on the diagonal line.

Fig. 17 is a cross-sectional view showing the bent portion 102c, in which the cross-sectional shape of Fig. 17(a) has substantially  
15 isosceles triangle shape having an apex 102c1 protruding outwards from a plane formed by the four straight tube portions 102b, and the cross-sectional shape of Fig. 17(b) has the substantially the isosceles triangle shape having a base 102c1' protruding outwards. The inner tube diameter (maximal diameter)  $\underline{a}$  of the bent portion  
20 102c corresponds the height of the isosceles triangle having the apex 102c1 of the bent portion 102c. The inner tube diameter D1 is formed to be 1.2 to 2.0 times the inner tube diameter of the straight tube portion 102b. In this embodiment, the inner tube diameter of the straight tube portion 2b is approximately 13.6 mm, and the  
25 inner tube diameter D1 at the bent portion 102c is approximately 27.2 mm, which is substantially twice the inner tube diameter of the

straight tube portion 102c. Further, it is to be noted that the minimum width  $b$  of the inner tube diameter is substantially the same as the length in the base direction of the isosceles triangle, i.e., the cross-sectional shape of the bent portion 102c, which is 13.6 mm being the same as the inner tube diameter of the straight tube portion 102b.

The wall thickness of the bent portion 102c is preferably the same as the wall thickness of the straight tube portion 102b or greater, in order to maintain the mechanical strength of the bent portions 102c. Particularly, the wall thickness of the apex 102c1 in the case of Fig. 17(a) easily becomes thin because the cross-sectional shape of the bent portions 102c is approximately isosceles triangle shape, and accordingly, the thickness is preferably 0.8 to 1.2 times the thickness of the straight tube portion 102b.

With the bent portion 102c in which the base 102c1' protrudes outward as shown in Fig. 17(b), since the discharge passage is formed inside, the non-discharge region can be formed large, thus providing high cooling effect and optimal coldest portion.

The operations of this embodiment will be described hereunder. The fluorescent lamp 101A (1), to which high-frequency electric power is inputted through the base 106, is lightened through the discharging of the low-pressure mercury vapor in the bulb 102. The fluorescent lamp 101A is lit (with the lamp input power of 20 W or more, lamp current of 200 mA or more, tube wall load of 0.05 W/cm<sup>2</sup> or higher, and the lamp efficiency of 50 lm/W or more. In addition, the lamp current density, which is the lamp current per

cross-sectional area of the straight tube portion 102b, is 75 mA/cm<sup>2</sup> or higher. In the case of the present embodiment, the lamp input power is 50W, lamp current is 380 mA, and lamp efficiency is 90 lm/W.

5        At the time of lighting the fluorescent lamp 101A, the coldest portion is formed to at least one bent portion 102c. In this embodiment, although the outer surface temperature of the straight tube portion 102b is 80°C when lit in a state that the glass bulb 102 is exposed to ambient temperature of 25°C, the temperature of the  
10       apex 102c1 of the bent portion 102c is 50°C, thereby confirming that a coldest portion is formed at this apex 102c1. The outer surface temperature of the apex 102c1 in the range of 40 to 65°C is suitable for the coldest portion, and if the mercury vapor pressure within the fluorescent lamp 101A is optimal as long as the coldest  
15       portion is within the temperature range, the lamp can be lit with the high lamp efficiency.

      Furthermore, although, in this embodiment, the glass bulb 102 is formed by locally bending a single straight-tube-shaped bulb 102a, a plurality of straight-tube-shaped bulbs may be connected at the  
20       ends to thereby form a bent portion of the glass bulb 102. For example, the plural straight-tube-shaped bulbs may be connected so as to provide joining portions by locally heating and fusing the end portions thereof and then blowing, and these joining portions are then connected and molded to form the bent portions 102c of the  
25       desired shape.

      Fig. 18 illustrates a case of locally heating and softening the

single long straight-tube-shaped bulb 102a and forming a plurality of bent portions 102c to obtain a square shape, as shown in Fig. 16, and in such case, there is shown the mutual dimensional relation between the heating width of the straight-tube-shaped glass bulb 102a, i.e., the burning width  $x$ , and the bending (curving) width  $c$  of the bent portion 102c.

As shown in Fig. 18, the bending width  $c$  is a length necessary for forming the coldest portion at the bent outside tube wall 102C0 of the bent portion 102c, indicating the length from the coldest point C0 formed at the bent outside tube wall 102C0 to the outer surface center of the radially-opposing bent inside tube wall 102Ci. The length of the burning width  $x$  of the straight-tube-shaped bulb 102a is affected by the length of the bending width  $c$ , and the width dimension  $W$  on the inner side of the bent portion (the length in the direction orthogonal to the length direction of the bending width  $c$  and parallel to the longitudinal direction of the straight-tube portion) decreases in proportional to the burning width  $x$ .

That is, in a case of locally heating and softening a single long straight-tube-shaped bulb 102a provided with the protective layer 103 and phosphor layer 104, which were formed preliminarily, and then bending the bulb 102a at a predetermined angle to obtain a square shape, the glass bulb 102b expands and shrinks at the bent portions 102c, and this expanding and shrinking causes peeling and cracking to the protective layer 103 and phosphor layer 104, causing factors of light flux deterioration at these portions, and therefore, it is desirable to make the width dimension  $W$  and the

burning width  $x$  lengths as small as possible.

Further, in the case of the same lamp current, the temperature of the coldest point  $C_0$  of the bent portion 102c is dependent on the bending width  $c$ .

5        Accordingly, in order to obtain the optimal coldest point temperate at this coldest point  $C_0$ , the bending width  $c$  is set to be longer than the outer tube diameter  $d$  of the straight-tube-shaped bulb 102a, and the bent inside tube wall 102ci is formed at an approximately straight (planar) wall 102cis connecting both edges of  
10   the inner side of the bent portion with the shortest distance on the straight line, thereby forming the burning width  $x$  at the minimal burning width  $x_a$ . Although the straight wall 102ci is preferably a straight plane, this is not restrictive, and the wall 102ci may be a somewhat curved surface. Further, it is desirable that the width  
15   dimension  $W$  is defined as the width dimension of the plane 102ci continuously changing from the straight tube portion 102b.

Accordingly, the bending width  $c$  and the width dimension  $W$  of the inner side of the bent portion are obtainable from the following equation [Numerical Expression 1].

20   [Numerical Expression 1]

$$d < c$$

$$0.5d < W < 3d$$

On the other hand, in a case of forming an arc-shaped wall 102cia for the bent inside tube wall 102Ci, the burning width  $w$  is a  
25   longer width  $w_a$  than the above minimal burning width  $w_{\min}$  ( $w_{\min} < w_a$ ), which is undesirable.



Fig. 19 is a front view of a fluorescent lamp 101B according to the twelfth embodiment of the present invention. This embodiment has a characteristic feature such that the tip 102e of one of adjacent straight tube portions 102b protrudes so as to extend in the axial direction of the straight tube portion 102b over the joining portion so as to form a protrusion 102e at the bent portion 102c of the glass bulb 2. The protruding length  $d_a$  of the protrusions 102e is within the range of 5.0 to 20 mm, and preferably of 0.2 to 1.2 times the length of the outer tube diameter of the straight tube portion. In the case of this embodiment, the protruding length  $d_a$  is approximately 10 mm.

Furthermore, the four bent portions 102c are formed by connecting five straight-tube-shaped bulbs 2b. That is, one side of the quadrate shape of the bulb is formed of straight tube portions 102b' and 102b' having the length half ( $1/2$ ) the length of the other sides, and electrodes (not shown) are sealed to the end portions 102d of the straight tube portions 102b' and 102b'. The base 6 is provided so as to straddle the end portions 102d of the straight tube portions 102b' and 102b'.

In this embodiment, since the bent portions 102c can be formed as tips 102e and it is not necessary to carry out special working, such as molding, after the connection of the straight bulb portions, the bulb 102 can be easily formed even in the case of connecting the plural straight portions 102b to form the bulb 102.

Further, in the fluorescent lamp 101c shown in Fig. 20, the protrusions 102e are not formed, but five straight tube portions

102b are connected and molded, subsequently, into a square shape. The fluorescent lamp according to this embodiment is one having a small diameter with a bulb tube outer diameter of 12 to 20 mm as in the twelfth embodiment. Thus, the connection of the bulb tips one  
5 another or connection of the bulb tip with the side surface can be easily done with higher mechanical strength than the connection of the pipe sides with small-diameter connecting tubes.

Fig. 21 is a front view of a fluorescent lamp 101F according to a first modification of the eleventh embodiment shown in Fig. 16.

10 This fluorescent lamp 101F has characteristic feature such that one side (the right side in Fig. 21) of the outer end portion, at which one electrode 105 of the squared glass bulb 101F is sealed, extends by a length  $L_a$  to a horizontal extension at the outer surface (lower  
15 surface) in the drawing of the electrode end portion, at which the other one electrode 105 is sealed. Other than the above structure, this modified embodiment has substantially the same structure as that of the eleventh embodiment.

Accordingly, with this fluorescent lamp 101F, the length of discharge path can be expanded by an amount of the extension  $L_a$   
20 at the end portion of the glass bulb 102, so the dark portion between electrode sealing end portions can be removed or reduced. Therefore, the visual appearance and entire light flux of the fluorescent lamp 101F can be improved.

Fig. 22(a) is a front view representing a fluorescent lamp 101G  
25 of the fourteenth embodiment of the present invention. This embodiment has a seamless squared glass bulb 12 formed in an

approximately box shape. The glass bulb 112 has a protective layer and fluorescent substance film formed on the inner surface thereof. Noble gas and mercury are sealed therein, and a pair of electrode sealing end portions 115a, 115a are formed by sealing a pair of electrodes 115, 115 at both end portions in the axial direction by line sealing or pinch sealing treatment. The paired electrode sealing end portions 115a, 115a are bent from the base portion thereof as shown in Fig. 22(b) in the parallel or vertical direction with respect to the single bending plane of the glass bulb 112 and inward to the squared glass bulb 112 so as to be arranged together horizontally as in Fig. 22 in a manner such that the portions other than the pair of electrode sealing end portions 115a and 115a form an approximately closed box shape. A base 116 shaped like a box cylinder is disposed on the outer surface of the paired electrode sealing end portions 115a, 115a so as to straddle the electrode sealing end portions 115a, 115a. The base 116 has a power supply member 116b composed of four pins 116a, for example, electrically connected to the paired electrodes 115 and 115.

According to the fluorescent lamp 101G, the glass bulb 112 has a ring shape structure closed in substantially box shape other at the light-emitting portions other than the pair of electrode sealing end portions 115a and 115a forming the dark portions, so that substantially the box shaped or ring shaped light emission can be realized without showing dark portions, thus improving the visual outer appearance.

Further, since the base 116 protrudes inside the squared

shaped glass bulb 112 without projecting outward therefrom, the electrode sealing end portions 115a and 115a can be prevented or reduced from damaging during packing and shipping of the fluorescent lamp 101G, and in addition, an outside space of the glass bulb 112 can be effectively utilized.

Further, as shown in Fig. 22(b), although, in this embodiment, the electrodes 115 are mounted to a flare stem 115b within the fluorescent lamp 101G, the flare stem 115b may be replaced with a button stem. According to this modification, the button stem is disposed lower, in height, than the flare stem, so that the length lb of the electrode sealing end portion 115a can be reduced by the length corresponding to this length so as to reduce the dark portion.

Fig. 23(a) through (e) are front views of fluorescent lamps 101H, 101I, 101J, 101K, and 101L, according to first through fifth modifications of the fourteenth embodiment of the present invention, respectively. The feature of the fluorescent lamp 101H according to the first modification shown in Fig. 23(a) resides in that the bent portions 112c1 is formed as arcs with a radius of curvature larger than the bent portion 112c of the fluorescent lamp 101G shown in Fig. 22(a), and structures other than this feature is the same as that of the fluorescent lamp 101G of the fourteenth embodiment mentioned above. In the following second to fifth modifications, substantially the same structure or configuration as that of the fourth embodiment will be adopted other than portions described hereunder with reference to Fig. 23(b) to (e).

The feature of the fluorescent lamp 101I according to the

second modification shown in Fig. 23(b) resides in that the bent portions 112c2 have been formed with a width greater than the bending width  $w_c$  of the bent portions 112c of the fluorescent lamp 101G shown in Fig. 22(a). According to this feature, since the bent portions 112c2 has a large bending width  $w_c$  as described above, the coldest portions can be formed at the bent portions 112c2.

The feature of the fluorescent lamp 101J according to the third modification shown in Fig. 23(c) resides in that the pair of electrode sealing end portions 115a and 115a are bent approximately parallel to the bending plane so as to protrude outwards from the squared shape of the glass bulb 112. According to this feature, since the pair of electrode sealing end portions 115a and 115a do not protrude inside the squared glass bulb 112, the squared inner space can be effectively utilized.

The features of the fluorescent lamp 101K according to the fourth modification illustrated in Fig. 23(d) and (e) reside in that the pair of electrode sealing end portions 115a and 115a are bent so as to protrude towards the back side surface of the drawing of Fig. 23 and (d) and front side surface thereof. According to this fluorescent lamp 101L, the electrode sealing end portions do not protrude inside or outside of the squared glass bulb 112, and the squared inner space and the outer space of the squared glass bulb 112 can be utilized effectively.

Fig. 24 is a schematic plan view illustrating a lighting fixture or device according to the fifteenth embodiment of the present invention. The lighting fixture has a fixture (device) body 110

having a flat-plate shape and is disposed such that fluorescent lamps 101x, 101y and 101z are combined to this fixture body 110 in a concentric manner. As such fluorescent lamps 101x through 101z, any one of the fluorescent lamps 101A through 101L according to the eleventh to fourteenth embodiments or combinations thereof may be applied with no problem.

The fixture body 110 is provided with an inverter as a lighting device, not shown so as to supply the high-frequency lamp power, 10 kHz or higher to the fluorescent lamps 101x, 101y, and 101z, thus realizing the high-frequency lighting.

The fluorescent lamp 101x is equivalent to a conventional 30 W type ring-shaped fluorescent lamp with an entire length l of the glass bulb 102 of 225 mm, the greatest inner width of 192 mm, an outer tube diameter of 16 mm, and a wall thickness of the glass bulb 102 of 1.0 mm. The rated lamp power of the fluorescent lamp 101x is 20 W, and the lamp is lit at high-output-characteristic lamp power of 27 W.

The fluorescent lamp 101y is equivalent to a conventional 32 W type ring-shaped fluorescent lamp with an entire length l of the glass bulb 102 of 299 mm, the greatest inner width of 267 mm, an outer tube diameter of 16 mm, and a wall thickness of the glass bulb 102 of 1.0 mm. The rated lamp power of the fluorescent lamp 101b is 27 W, and the lamp is lit at the high-output-characteristic lamp power of 38 W.

The fluorescent lamp 101z is equivalent to a conventional 40 W type ring-shaped fluorescent lamp with an entire length l of the

glass bulb 102 of 373 mm, the greatest inner width of 341 mm, an outer tube diameter of 16 mm, and a wall thickness of the glass bulb 102 of 1.0 mm. The rated lamp power of the fluorescent lamp 101c is 34 W, and the lamp is lit at the high-output-characteristic lamp power of 48 W.

Figs. 25 to 27 represent the sixteenth embodiment of the fluorescent lamp according to the present invention, in which Fig. 25 is a front view of a wire lamp in a state of the base being removed, Fig. 26 is an enlarged cross-sectional view of the tube end portion, and Fig. 27 includes illustrations for explaining the steps of shaping the discharge vessel.

In these drawings, the fluorescent lamp FL is provided with a discharge vessel DV and a base B. The discharge vessel DV is an approximate quadrate in its entire structure and has one bent discharge path therein. Further, the discharge vessel DV comprises a glass bulb 202, a protective layer 203, a phosphor layer 204, and a pair of electrodes 205 and 205. The discharge vessel further includes a discharge medium containing amalgam 202g and 202g sealed therein.

The glass bulb 202 is formed by locally heating, softening and bending a single straight cylindrical glass tube so as to provide an approximate quadrate shape entirely. Three straight tube portions 202b and two short straight tube portions 202b forming the four sides of the square shape, and four bent portions 202c forming the corner portions and a pair of ends 202d are connected and disposed on the same plane. The pair of tube end portions 202d and 202d

comprise a pair of fine tubes 202f and 202f.

The three straight tube portions 202b make up three adjacent sides of the quadrate shape, and the two short straight tube portions 202b extend in mutually opposing directions so as to constitute the remaining one side. The bent portions 202c connect the adjacent pair of straight tube portions 202b at right angles. The pair of ends 202d and 202d are composed of the free ends of a pair of straight tube portions 202b and 202b and are sealed before the bending of the glass tube by sealing flare stems S of respective electrode mounts M to the ends of the glass bulb.

The electrode mount M is an assembly composed of a flare stem H, a fine tube 202f, an electrode 205 and a lead wire 202j, which are preliminarily assembled, and a pair of such assemblies are sealed in the glass tube by fusing the flare portion of the flare stem H to the end portions 202d of the glass tube. Then, the glass bulb 202 is sealed off, and as mentioned hereinlater, the fine tube 202f is connected to the glass bulb 202, the electrodes 205 are sealed and the lead wires 202j extend from the electrodes 205. As shown Fig. 26, both the end portions 202d of the glass bulb 202 are subjected to mold shaping at the time of sealing the flare stem H, thereby forming a narrow portion 202k.

The pair of fine tubes 202f extend outwards from the pair of ends 202d of the glass bulb 202. The inner ends of the fine tubes 202f communicate with exhausting holes in the glass bulb 202. On the other hand, the outer ends of the fine tubes 202f are sealed with the inner face protruding inwards, as shown in Fig. 26. Furthermore,



the paired fine tubes 202f are bent at the front ends thereof so as to provide approximately right angles in parallel to each other and extend in directions approximately orthogonal to the tube axis.

Further, the paired fine tubes 202f extend in a long shape before the tips 202f2 are sealed.

Next, the method for manufacturing the fluorescent lamp FL according to the present embodiment will be described with reference to Fig. 27.

This manufacturing method is approximately the same as the manufacturing method described with reference to Fig. 2, and therefore, only points differing from the method shown in Fig. 2 will be described hereunder in detail.

First, as shown in Fig. 27(a), a first bent-portion-formation preordination portion is heated and softened with a gas burner B, and as shown in Fig. 27(b), the bending is performed so as to provide the angle between straight tube portions 202b and 202b to be 90°, following which a first bent portion 202c is formed to a predetermined shape by molding or like step. Subsequently, the bent-portion-formation preordination portion adjacent to the first bent portion 202c is also heated and softened with the gas burner B and subjected to the bending and molding steps, thereby forming the second bent portion 202c as shown in Fig. 27(c). Similarly, the bent-portion-formation preordination portions are sequentially heated and softened with the gas burner B and subjected to the bending and molding steps as shown in Fig. 27(d) and (e), thereby forming the discharge vessel DV to be the quadrate shape such as

shown in Fig. 25 with the four bent portions 202c being formed. Furthermore, the middle portions of the paired fine tubes 202f and 202f are bent approximately at right angles downwards in the drawing such that the tip portions thereof extend parallel in a long shape. The fine tubes 202f are shortened at the time of being sealed after the sealing in the discharge medium.

In the exhausting/sealing process, the discharge medium is sealed after the exhaust of the interior of the discharge vessel DV. The pair of fine tubes 202f and 202f extending from the pair of ends 202d of the discharge vessel DV are connected to an exhausting device, not shown, and the discharge vessel DV is simultaneously drawn from both end sides 202d. Accordingly, exhaust is surely performed, even in the case of the discharge vessel having a polygonal shape. Following this exhausting step, the noble gas and amalgam 202g is sealed into the discharge vessel DV by way of one of the fine tubes 202f. Subsequently, the middle portion of the pair of fine tubes 202f are heated and melted so as to close the tip of the portion remaining on the discharge vessel DV side, thereby performing the sealing step. The inner surface of the tip portions 202f2 of the fine tubes 202f, sealed in this manner, protrude inward.

The other embodiments of the fluorescent lamp LF according to the present invention will be further described hereunder with reference to Fig. 28 through Fig. 32. Note that in the drawings, same or like reference numerals are added to portions or members corresponding to those shown in Fig. 25 through Fig. 27 and descriptions thereof are omitted herein.

Fig. 28 illustrates the seventeenth embodiment of the present invention, in which Fig. 28(a) is a schematic view of a discharge vessel, partially cut away, before the exhaust step, and Fig. 28(b) is a side view thereof. This embodiment differs in that the middle  
5 portion of the fine tubes 208f of this embodiment is bent at a right angle to the plane including the polygonal portion of the glass bulb 202. Such structure is advantageous for the exhausting/sealing device.

Fig. 29(a) represents the eighteenth embodiment of the present invention and is a front view of a wire lamp in a state of the base  
10 being removed.

That is, the glass bulb 202 is formed of the three bent portions 202c and the pair of fine tubes 202f. The end 202d of the free end sides of the straight tube portions 202b are arranged in close  
15 proximity to each other at approximately right angles on both ends thereof.

As shown in Fig. 29(a), one fine tube 202f protruding from the end 202d of the straight tube portion 202b extending vertically of one glass bulb 202 extends straight with respect to the tube axis.  
20 On the other hand, the fine tube 202f' protruding from the end 202d of the straight tube portion 202b extending horizontally in the drawing of one glass bulb 202 bends approximately at a right angle at the middle portion thereof to make approximately parallel to one fine tube 202f.

25 Fig. 29(b) is a front view of a wire lamp according to the nineteenth embodiment of the present invention. In this

embodiment, the configuration of the pair of fine tubes 202f differs from the lamp of, in comparison, the glass bulb 202 according to the embodiment shown in Fig. 29(a).

That is, the pair of fine tubes 202f both curve gently at the  
5 middle portion so that the front ends thereof extend generally in parallel towards the outer side along the diagonal line of the square shape.

Fig. 30 through Fig. 32 represent the twentieth embodiment of the present invention, a feature of this embodiment resides in a pair  
10 of fine tubes 201g and 201h having a shape improved over the fine tubes 202f and 202f illustrated in Fig. 28(b). Other than such shape or structure, the configuration is the same as the pair of fine tubes 202f and 202f.

That is, the inner end portions of the paired fine tubes 201g  
15 and 201h are communicated with the inside portion of the glass bulb 202, and these tubes extend in the axial direction thereof such as fine tubes 202f and 202f shown in Fig. 28 with the outer end portions 201g2 and 201h2 extending outward from the pair of ends 202d and 202d of the glass tube 202.

20 As shown in Fig. 30 and in Fig. 31 which is a plan view of Fig. 30, the middle portions of the outer end portions 201g2 and 201h2 of the pair of fine tubes 201g and 201h are curved in an arc shape so as to extend perpendicularly, and both curved portions 201g2a and 201h2a thereof intersect in the direction penetrating the  
25 drawing paper in Fig. 30 (in the diameter direction of the exhaust tubes 201g and 201h) with a predetermined gap therebetween.

That is, as shown in Fig. 30 and Fig. 31, the outer end portions 201g2 and 201h2 of the pair of fine tubes 201g and 201h are formed with the same shape and same size, and the horizontal portions 201g2b and 201h2b extending in the parallel direction along the center axis O of the end portions 202d toward the end portion 1d at the other side (opposing side), the curved portions 201g2a and 201h2a and the standing portions 201g2c and 201h2c standing perpendicularly from the curved portions 201g2a and 201h2a are integrally formed continuously from one of the paired end portions 202d and 202d of the glass bulb 202.

That is, as shown in Fig. 31, the horizontal portions 201g2b and 201h2b of the pair of fine tube outer end portions 201g2 and 201h2 extend towards the mutually opposing end portions 202d and 202d of the glass bulb 202 along the central axis O thereof, and in order to avoid collision of these two portions, the tip portions thereof are formed to be continuous into straight-tube shaped standing portions 201g2c and 201h2c in an arc shape in the erecting direction (perpendicular direction) as shown in Fig. 30 with an inclination of a predetermined angle (exhaust tube protrusion angle) towards the front and back directions of the inner side and outer side of the quadrate structure of the glass bulb 202 at a point just before the center point C at which the front ends come into contact to each other.

At this time, the gap l between the pair of end portions 202d and 202d of the glass bulb 202 is formed to be 30 mm, for example, the curvature radius R of the curved portions 201g2a and 201h2a to

be 20 mm, and the exhaust tube protrusion angle formed to be  $45^\circ$  in mutually opposing directions as shown in Fig. 32. Further, that the curvature radius R may be preferably within 15 mm to 30 mm.

Further, the reference numerals 201g3 and 201h3 in Fig. 30 and Fig. 31 denote a pair of ring-shaped rubbers externally fitted and fixed to the erected portions 201g2c and 201h2c of the pair of fine tubes 201g and 201h. In the exhausting step, opened front ends of a vacuum pump head of an exhausting device, not shown, are externally fitted in an airtight manner to the outer surface of the ring shaped rubbers 201g3 and 201h3, so that the inside of the glass bulb 201 is evacuated, and subsequent to this exhausting step, the discharge medium is supplied into the glass bulb 201 and sealed therein. Following the exhausting and sealing steps, the exhaust tube outer end portions 201g2 and 201h2 are pinched off by a predetermined lengths so as to be stored in the base B and covered. Four electricity receiving pins 207, for example, are disposed to stand on the outer circumference of the base B, and the electricity receiving pins 7 are electrically connected to the four lead wires 201g, respectively, at the inner ends thereof.

According to this fluorescent lamp FL, although the glass bulb 202 can be evacuated by the pair of fine tubes 201g and 201h almost simultaneously from both ends thereof, the discharge medium may be sealed in almost simultaneously from both ends of the glass bulb 202 through the pair of fine tubes 201g and 201h.

Accordingly, even in the case where the glass bulb 202 is long and polygonal shape, the exhausting is well performed, so that residual

impure gasses in the discharge vessel are dramatically reduced. Consequently, the luminous flux maintenance factor of the fluorescent lamp is markedly improved.

In addition, since the curvature radius of the curved portions  
5 201g2a and 201h2a of the pair of fine tubes 201g and 201h is 15 to 30 mm, the mercury inserted from the fine tubes 201g and 201h smoothly moves through the erected portions 201g2c and 201h2c and horizontal portions 201g2b and 201h2b of the fine tubes 201g and 201h with own weight and is hence inserted into the glass bulb  
10 202.

Thus, the mercury can be sealed into the glass bulb 202 speedily and surely, and the sealing efficiency can be improved.

Furthermore, in the case where the curvature radius of the curved portions 201g2a and 201h2a of the pair of fine tube outer  
15 end portions 201g2 and 201h2 is smaller than 15 mm, the erecting angle of the curved portions 201g2a and 201h2a becomes a sharp angle, closer to a right angle, leading to a difficulty in inserting mercury into the fine tube outer end portions.

On the other hand, in the case where the curvature radius of  
20 the curved portions 201g2a and 201h2a exceeds 30 mm, the erecting angle of the curved portions 201g2a and 201h2a becomes a blunt angle. Accordingly, the amount of enlargement of the erected portions 201g2c and 201h2c of the fine tubes 201g and 201h enlarging towards the sealing end sides 201d of the glass bulb 201  
25 increases, leading to enlargement of the gap between the pair of sealing end portions 202d and 202d, causing a problem of reduced

lamp efficiency.

According to the present embodiment, since the curved portions 201g2a and 201h2a of the fine tubes 201g and 201h have a curvature radius of 15 to 30 mm, the problems mentioned above  
5 could be eliminated beforehand.

In addition, since the horizontal portions 201g2b and 201h2b of the pair of the outer end portions 201g2 and 201h2 of the fine tubes 201g and 201h are inclined so that the center axes thereof are mutually offset, the horizontal portions 201g2b and 201h2b of the  
10 pair of the outer end portions 201g2 and 201h2 of the fine tubes 201g and 201h could be extended near the sealing end portions 201d and 201d without contacting (colliding) the horizontal portions 201g2b and 201g2b with each other.

Accordingly, the length of the horizontal portions 201g2b and  
15 201h2b of the pair of fine tubes 201g and 201h can be made longer without enlarging the gap between the pair of sealing end portions 202d and 202d of the glass bulb 202 which are dark portions, thereby allowing the radius of curvature of the curved portions 201g2a and 201h2a to be easily made larger without increasing the  
20 dark portions.

Furthermore, since shape of the glass bulb 202 is formed into a rectangular ring, and the pair of sealing end portions 202d and 202d which are the axial end portions of the ring shape are disposed facing one another with a predetermined gap l therebetween, even in  
25 the case where the glass bulb 202 has the long axial length, the pair of fine tubes 201g and 201h standing on the pair of sealing end



portions 202d and 202d are disposed in mutually close positions, so that the exhausting processing can be easily performed via the pair of fine tubes 201g and 201h. Moreover, the exhaust of the glass bulb 202 can be simultaneously performed via the pair of fine tubes 201g and 201h standing on both the sealing end portions 202d and 202d of the glass bulb 202, so that the exhaust can be surely performed even in the case of the polygonal, such as quadrate, glass bulb 202. Accordingly, the luminous flux maintenance factor of the obtained fluorescent lamp FL can be improved.

It is further to be noted that the embodiments described above have been proposed with reference to the cases in which the glass bulb is formed in the quadrate shape, the present invention is not restricted to this shape and may be applied to any other shape such as rectangular, circular, or double-ring shaped bulbs, and like. The outer diameter and axial direction length of the glass bulb is not also restricted to those described with reference to the embodiments mentioned above.

#### Industrial Applicability

As described above, according to the fluorescent lamp of the present invention mentioned above, thermal deterioration of the phosphor layer formed in the straight tube portion can be reduced and deterioration in the initial light flux can be suppressed, enabling lighting a higher efficiency.

Furthermore, there is provided a fluorescent lamp, which is thin due to the small tube diameter, is capable of lighting with high efficiency with improved light output characteristics, and has an

excellent luminous flux maintenance factor.